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ENHANCED USER EVALUATION AND DEMONSTRATION OF THE COMBAT VEHICLE CREW HELMET-MOUNTED DISPLAY (CVCHMD) SYSTEM

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This report describes testing of the Combat Vehicle Crew Helmet-Mounted Display (CVCHMD) Enhanced User System, which was developed to provide electronic battlefield information to a tank commander who is out of the hatch. The information is presented to the commander on a helmet-mounted display using formats similar to those used on displays inside the tank. The enhanced user system was tested over three weeks at the Army's Mounted Warfare Battle Laboratory using the Distributed Interactive Simulation facility. The CVCHMD enhanced user system provides the tank commander with long-range situational awareness without sacrificing short-range situational awareness.

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Preface

This report describes the Enhanced User Evaluation and Demonstration of the Combat Vehicle Crew Helmet-Mounted Display (CVCHMD) System which was performed between March 1994 and August 1997 under contract number DAAK60-94-C-0028. The work was undertaken by Honeywell Technology Center, Honeywell, Inc., Minneapolis, MN, and sponsored by the Defense Advanced Research Projects Agency (DARPA), Arlington, VA, and monitored by the U.S. Army Soldier Systems Center, Soldier and Biological Chemical Command, Natick, MA. The CVCHMD System provides electronic battlefield information to tank commanders while they are out of the tank hatch.

ENHANCED USER EVALUATION AND DEMONSTRATION OF THE COMBAT VEHICLE CREW HELMET-MOUNTED DISPLAY (CVCHMD) SYSTEM

Section 1
Summary

This report describes testing of the Combat Vehicle Crew Helmet-Mounted Display (CVCHMD) Enhanced User System, which is a system developed to provide electronic battlefield information to tank commanders while they are out of hatch. The information is presented to the commander on a helmet-mounted display using formats similar to those used on displays inside the tank. The enhanced user system was tested over three weeks at the Army's Mounted Warfare Battle Laboratory (MWBL) using the Distributed Interactive Simulation (DIS) facility. The CVCHMD enhanced user system provides the tank commander with long-range situational awareness without sacrificing short-range situational awareness.

This report contains a brief system overview starting with changes that were made to the system as a result of a user jury review conducted in the spring of 1994. A previous report titled "Enhanced User Evaluation and Demonstration of the Combat Vehicle Crew Helmet-Mounted Display (CVCHMD) System: User Jury Review #1" describes the initial system design and development leading up to the user jury review. The results of the actual DIS testing are reported in a separate document written by the Army's Test and Evaluation Command (TECO). In addition, a large amount of subjective information was learned from soldier comments made outside the testing period.

Section 2
Introduction

On today's battlefield, commanders of the M1A2 tank have access to a large amount of electronic battlefield information using the Commander's Independent Display (CID) located in the turret of the M1A2. The CID provides the current location and heading of the commander's tank as well as any other friendly tanks in the area. The CID also provides a map of the battlefield with landmarks and other information drawn on overlays, as well as communications with other units through the sending and receiving of specialized reports. Another function of the CID is the Commander's Independent Thermal Viewer (CITV), which provides a magnified thermal image of the battlefield. All of this information on the CID provides the tank commander an excellent long-range view of the battlefield.

Tank commanders would, however, prefer to spend most of their time outside the turret, where they can keep an eye on the local battlefield, watching for near-range threats such as unpassable terrain or even collisions with friendly vehicles. The goal of the CVCHMD enhanced user program is to provide much of the functionality of the CID on a helmet-mounted display, so the tank commander has access to the digital battlefield information while remaining out of the hatch. This information must be displayed in a way that does not reduce the commander's vision and situational awareness of the local battlefield.

The HMD used by the enhanced user system was developed by Honeywell on the CVCHMD program. It uses a 640x480 active matrix liquid crystal display (AMLCD) developed by Kopin Corp. The HMD is see-through and built into a biocular goggle that provides the same display to each eye with 100% overlap. The actual color of the displays is green. The convergence of the eyes as well as the brightness of the displays are adjustable using an infrared (IR) remote. The goggle weighs about 700 g.

There were two main reasons for redesigning the CID screens for presentation on an HMD. One driving factor was to leave as much as possible of the screen clear to allow for maximum external visibility. Discussions with soldiers and domain experts helped to design a base screen that kept the center and sides of the display clear. The greater field of view of the HMD over the CID allowed a reduction in the font sizes for much of the information on the screens. This allowed text to be made smaller and moved away from the center of the screens without sacrificing readability.

A second impetus for redesigning the CID screens was to provide screen navigation capabilities for out-of-hatch operation. Changes were required in screen navigation because the CID makes use of six hard buttons inside the turret that are not reachable from outside the turret. These buttons are used for screen navigation and menu selections. The design of the enhanced user screens had to incorporate all of the navigation and menu functions within the screens themselves. This was accomplished by using selectable buttons on the screens and a cursor control device that could be used to move a cursor and make selections.

A prototype enhanced user system was tested using the Army's DIS facility at the Mounted Warfare Battle Laboratory in Fort Knox, Kentucky, over a three-week period in February 1995. Although the results of the actual testing are reported in a separate document written by the Army's Test and Evaluation Command, a large amount of subjective information was learned

from soldier comments made outside the testing period. Much of what was learned came from comments the soldiers made during the initial system training and through post-test interviews. These subjective results are discussed in Sections 4 and 5 of this report.

Testing of the enhanced user system in the DIS facility showed that it would be a valuable enhancement to the M1A2 tank. The soldiers reported that they would use it and it would increase the time they would spend out of hatch. The general consensus was that the screen layouts and system functionality were good, needing only small changes.

Section 3
Methods, Assumptions, and Procedures

3.1 Changes as a Result of the First User Jury Review

Based on comments from the first user jury review held at Fort Knox in the spring of 1994, changes were made to the enhanced user system screens. The most significant change was to add functionality to the screens so the users could get a better feel for the system's behavior. After the user jury review, it was clear that individual screens could not be designed without taking into account their behaviors and the interactions between the screens.

Functional screens were prototyped in Supercard and hosted on a Macintosh. The Supercard implementation allows users to bring up menus, enable and disable functions, and move between screens. An existing SUN-based CID simulation was augmented with the enhanced user screens and integrated with a Honeywell-developed HMD for the DIS demonstration and testing.

The functional implementation of the enhanced user screens included the addition of shortcut buttons to streamline some tasks. One shortcut button on the base screen allows quick jumping to the report-generation screen and then quick jumping to the contact report screen. Another shortcut button allows a return to the base screen from any other screen.

Other changes resulting from comments made during the user jury include eliminating radio net information from the top line of the base screen and eliminating the stadia choke reticle. The users did not feel they would make use of either function while out of hatch.

Responses from users helped shape the configuration of the compass that appears at the top center of all screens. User comments also led to increasing the font size for several of the screens. User responses also helped narrow the types of reports needed for an out-of-hatch operation to spot, contact, and call for fire reports.

Some method of entering numbers is required to fill out the reports that include a size field. The two options for entering numbers with a cursor control device are to provide an on-screen numeric keypad or use some type of increment/decrement mechanism. Discussions with the users revealed that it would be extremely difficult to make numeric selections by pointing to a numeric keypad with a cursor control device. Based on these comments, a new numeric entry screen was developed that includes increment, decrement, and done buttons.

3.2 Screen Descriptions

Figure 1 shows the hierarchy for the enhanced screens. The screens shown in the shaded region are accessed at any time from any of the other screens. These screens include the tactical, incoming messages, CITV, and report screens. At the top of the hierarchy is the base screen, which is the basis for all other screens.

The base screen, shown in Figure 2, is the least cluttered of all the enhanced screens. It includes only the most essential information and links to the most important functions the commander may need. It is expected that the tank commander will use the base screen most of the time while

out of hatch. The base screen allows the commander to monitor for incoming messages and keep track of the tank's position while still observing the outside world.

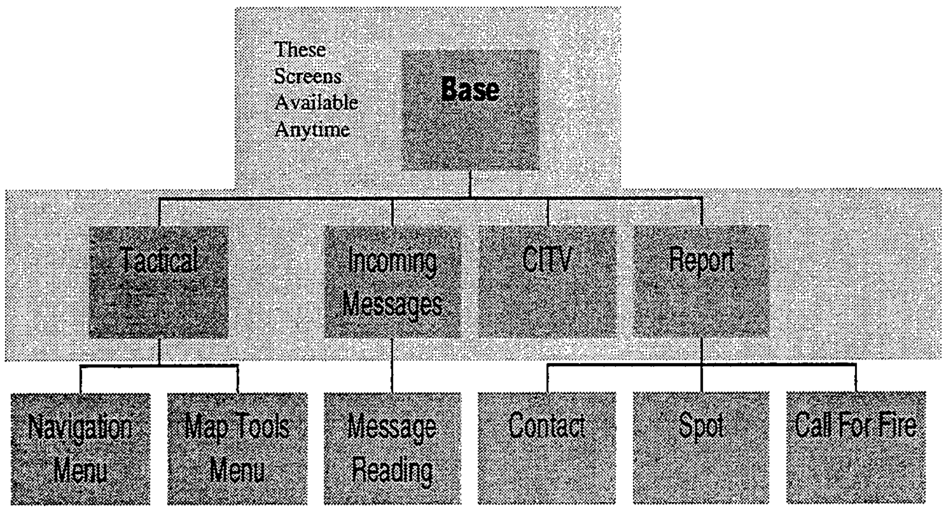

Figure 1. Enhanced User HMD Screen Hierarchy

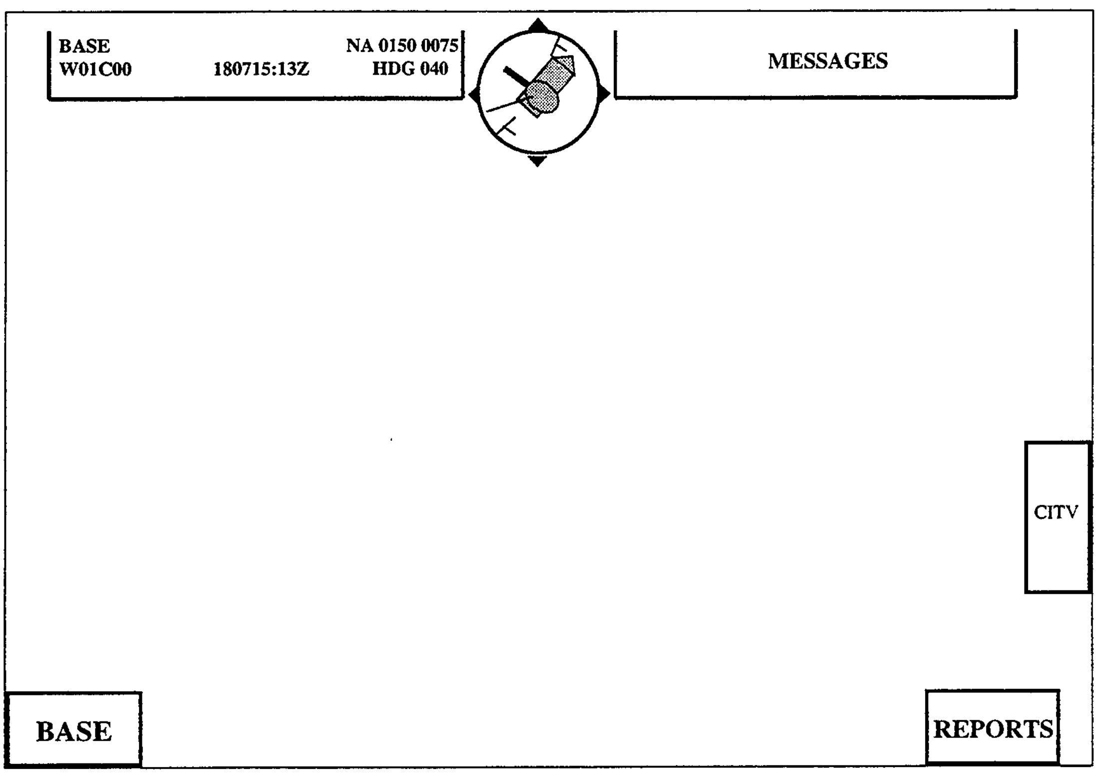

Figure 2. Base Screen

The base screen includes a top line similar to the top bar in the standard CID screens, a clear central area, and a few buttons for accessing other screens. The left side of the base screen top line shows the screen name and the warning and caution count. Next along the top line is the current time. To the right of the time are the current grid coordinates and the current heading of the hull. The circular icon at the center of the top line is a compass that shows the hull heading, turret heading, and CITV scanning direction and stops. Selecting the compass with the cursor

switches to the tactical screen. At the far right of the base screen top line is the incoming message box. This box shows the title and time of the most recently received message in the message queue. If there are no messages in the message queue, the box will be empty. Selecting the message box with the cursor will bring up the incoming message screen.

Unlike standard CID screens, the base screen does not have any graphics in the center of the display. The central portion of the visual field is kept clear to allow the user to monitor the outside world while using the base screen. The base screen includes two buttons: one for accessing the report screen and one for the CITV screen.

After the base screen, the screen most often used is the tactical screen, shown in Figure 3. The tactical screen is brought up by using the cursor to select the compass from any of the other screens. The tactical grid screen includes all of the information from the base screen, with the addition of a map of tactical information and a menu of options for manipulating the map. The map fills the central portion of the screen and contains grid lines as well as overlay information. The menu line at the bottom of the screen provides tools for manipulating the map and overlays.

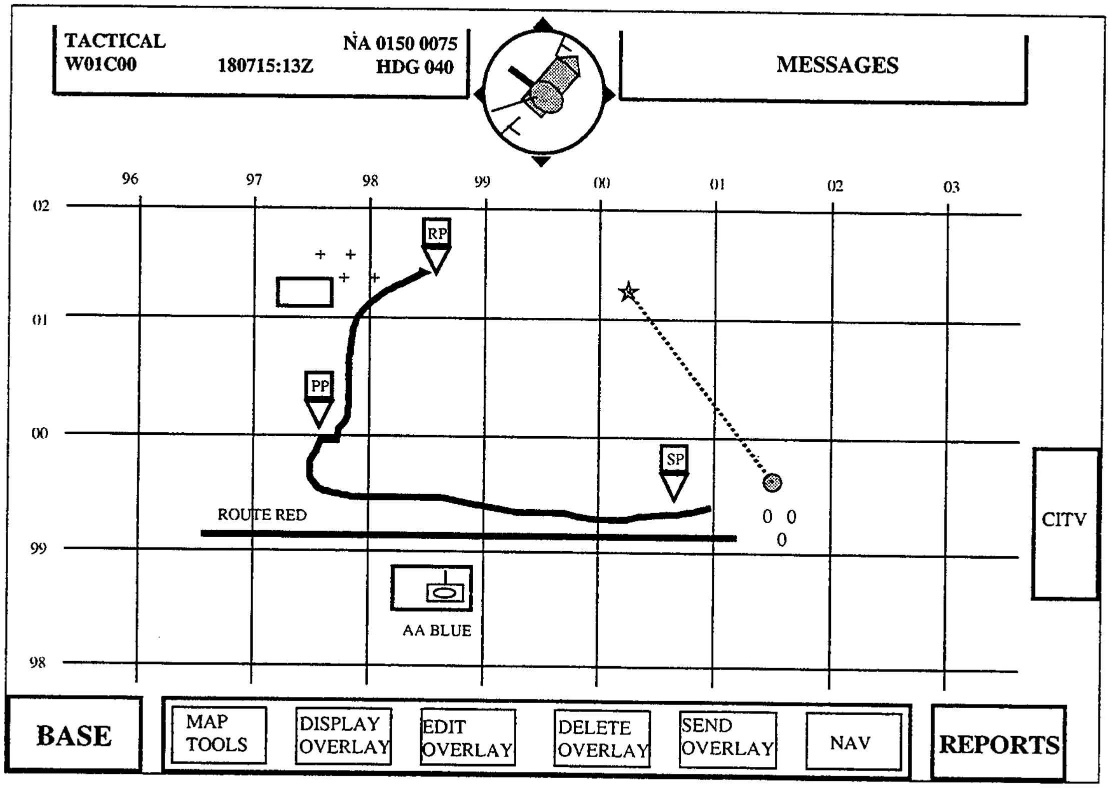

Figure 3. Tactical Screen

The base button in the lower left corner of all the screens allows the user to jump back to the base screen at any time. The base button functions like a quick clear switch as well as a system reset, taking the user back to a starting point they know. The tactical screen also includes a report button and a CITV button to access those screens.

Selecting the compass from the tactical screen will bring up a quarter tactical screen, as shown in Figure 4. This screen contains a reduced-size tactical map that can be placed in any of the four quadrants of the screen. The purpose of the quarter tactical grid is to allow the user to monitor

map information while still having some external visibility. Selecting the compass from the quarter tactical grid screen will return the user to the full tactical screen.

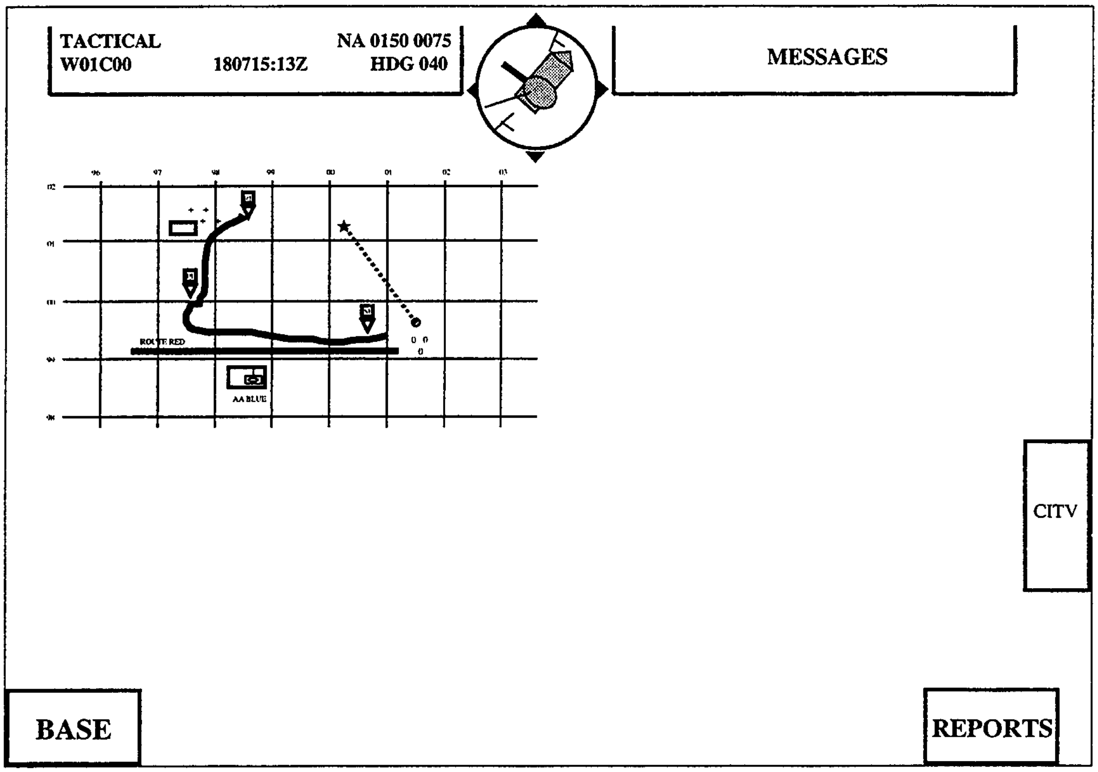

Figure 4. Quarter Tactical Screen

Figure 5 shows the incoming message screen, which is brought up by using the cursor to select the message box at the top right corner of any other screen. The incoming message screen shows a list of message titles in the message queue. The cursor is used to select a message for reading. When a message has been selected, the incoming message screen changes to the message reading screen shown in Figure 6.

The message reading screen shows the text of the selected message and includes a menu at the bottom of the screen to provide options for dealing with the message. The user can forward the message up the command chain, delete the message, or return to the previous screen without doing anything to the message. The return button takes the user back to the screen that was accessed before the incoming message screen. The menu at the bottom of the message reading screen also includes a button to bring up a menu of tools for manipulating the tactical map.

Another group of screens provides report writing functions. When the reports button is selected, it brings up the report screen shown in Figure 7. The report screen is similar to the base screen, with the addition of menu selections for report types. The menu selections allow the user to select among contact, spot, or call for fire reports. While in the reports screen, the button in the lower right corner has changed from a reports button to a contact report button. This is a shortcut to jump to the contact report screen, which is the most often used report screen.

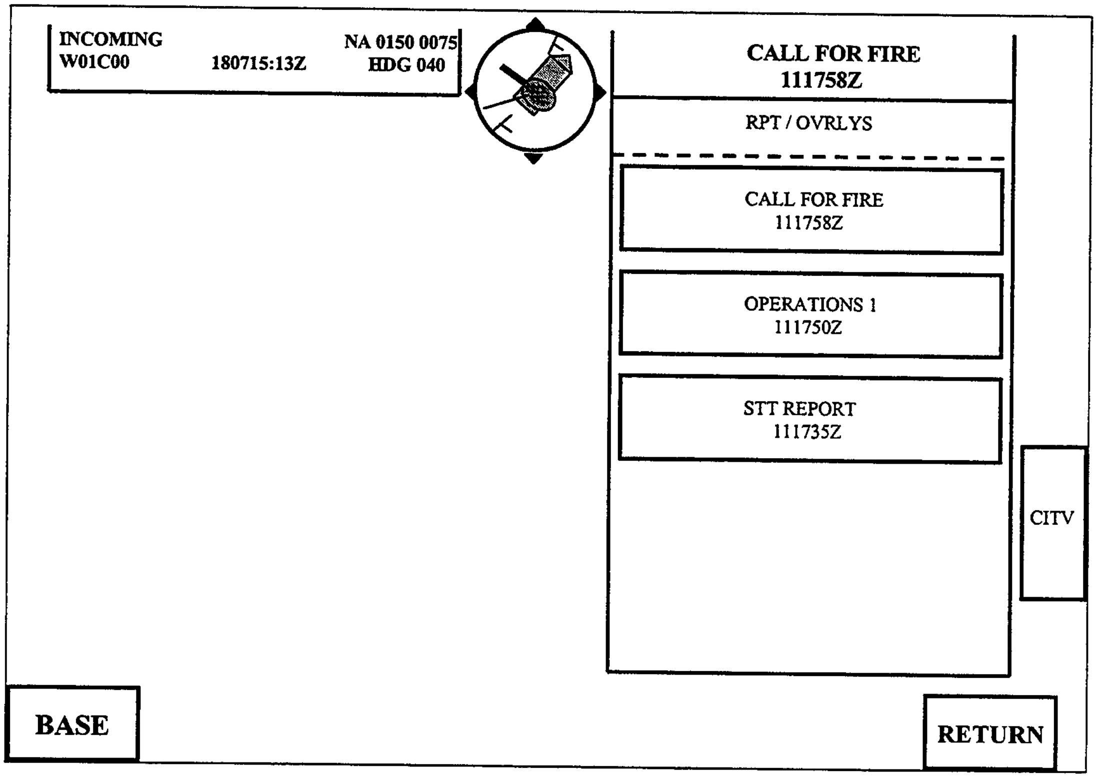

Figure 5. Incoming Message Screen

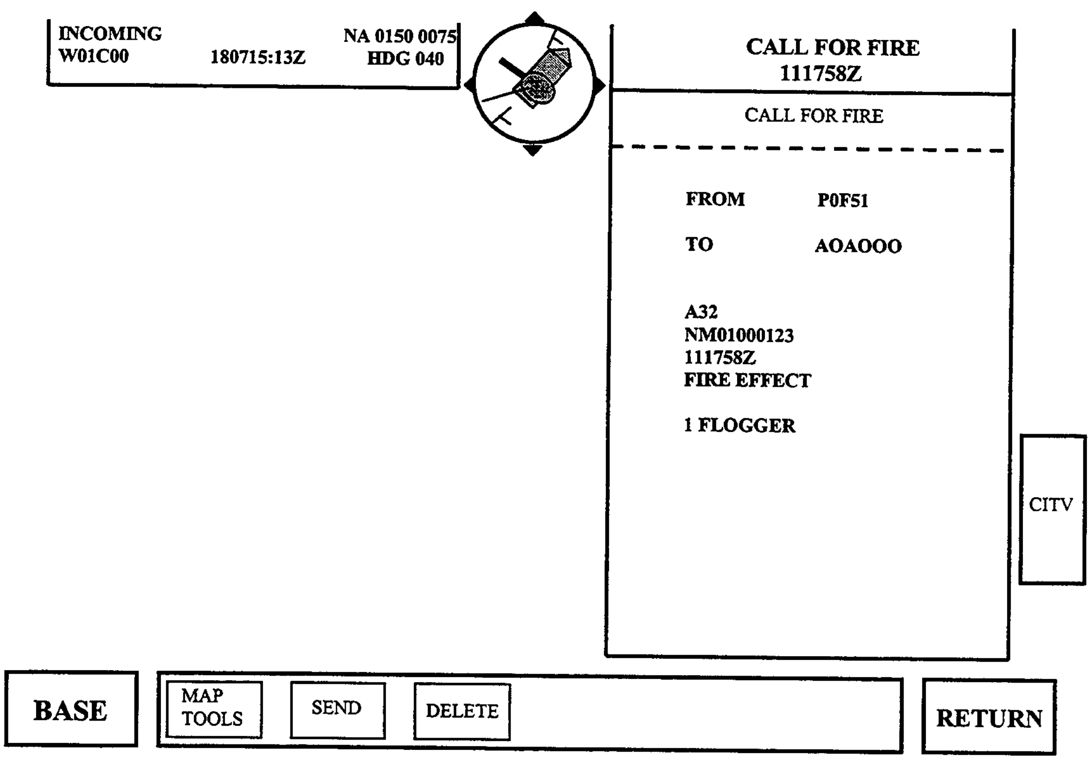

Figure 6. Incoming Message Reading Screen

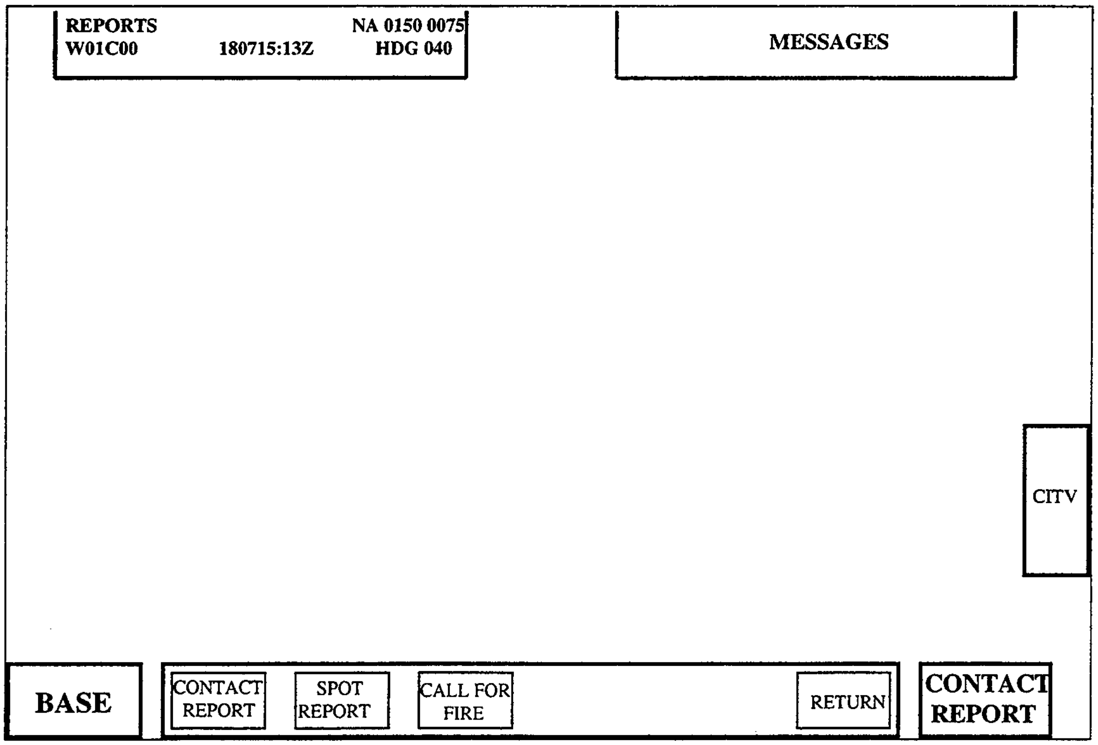

Figure 7. Report Screen

From the report screen, selecting either of the contact report buttons will bring up the contact report screen, as shown in Figure 8. The contact report screen has a window containing the text of a partially completed contact report. The current time and sender's ID fields have already been filled in. The location field contains a default value of the location of the last target lased by the gunner, but it can be changed with the cursor if desired. The contact report text includes a menu of target types that the user must select with the cursor. When the user selects a target type, the group size menu appears, as shown in Figure 9. The size count defaults to a value of one but can be incremented or decremented using the cursor. When the group size count shown is correct, the user selects return or done. The completed contact report is then displayed, as shown in Figure 10. Menu items at the bottom of the screen allow the user to send the message, add a call for fire to the message, return to the report screen without sending the message, or bring up a map tools menu to prepare a map overlay for inclusion with the report. Note that the button in the lower right corner sends the report, which would be the most used function from this screen.

The button in the lower right-hand corner has been set up as a shortcut for quickly sending a contact report. To send a quick contact report, the user selects the lower right-hand button to get the report screen and then selects it again to get the contact report screen. The user then chooses the target type and selects the button in the lower right to send off the report with a default group size of one. The spot report screens are almost identical to the contact report screens with only slight changes in the detail of the target descriptions. The call for fire report is similar but includes a request for action against the target.

The CITV screen, shown in Figure 11, looks exactly like the base screen, except the entire screen is overlaid on top of imagery from the CITV sensor. Future CITV screens will provide access to menus for control of CITV parameters such as magnification, contrast, and scan patterns. When

in the CITV screen, selecting the CITV button will turn off the CITV imagery. All the other buttons function the same as they do in the base screen.

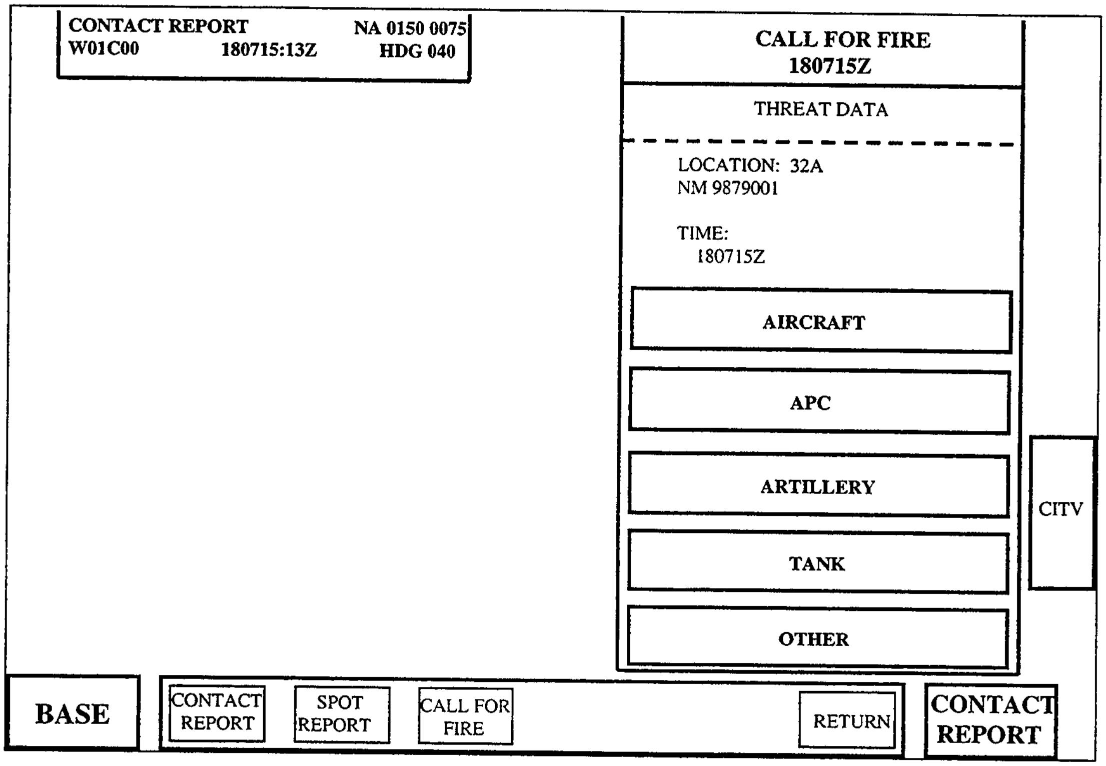

Figure 8. Contact Report Threat Selection Screen

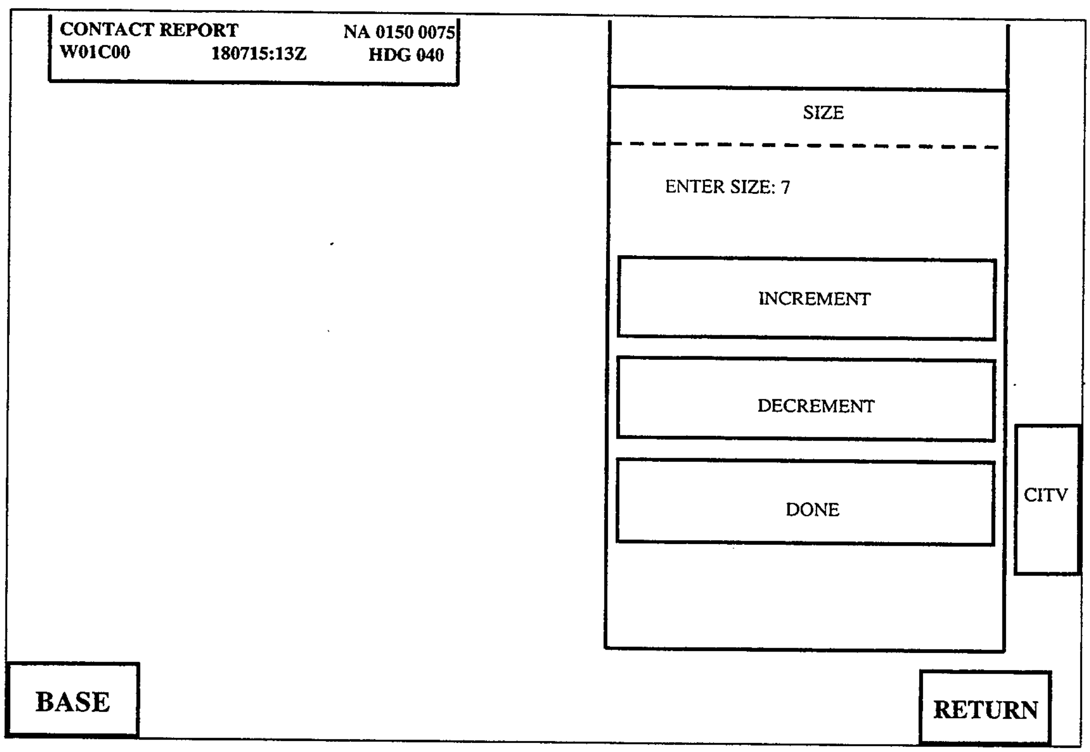

Figure 9. Contact Report Threat Size Selection Screen

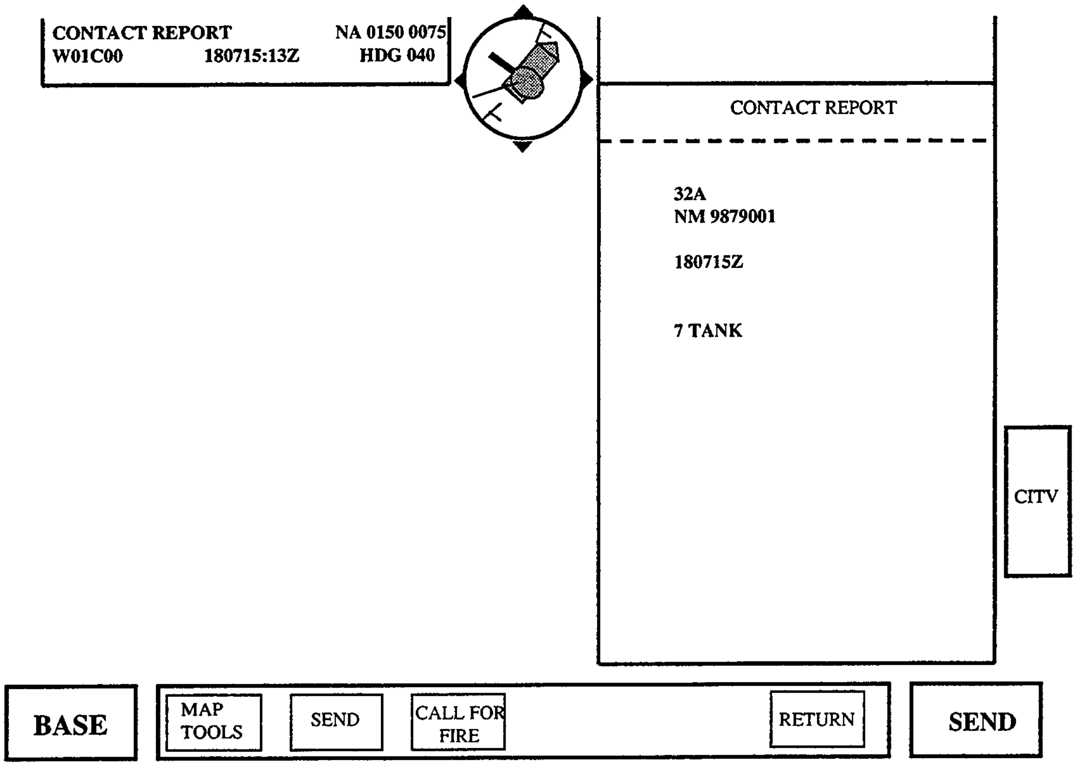

Figure 10. Contact Report Sending Screen

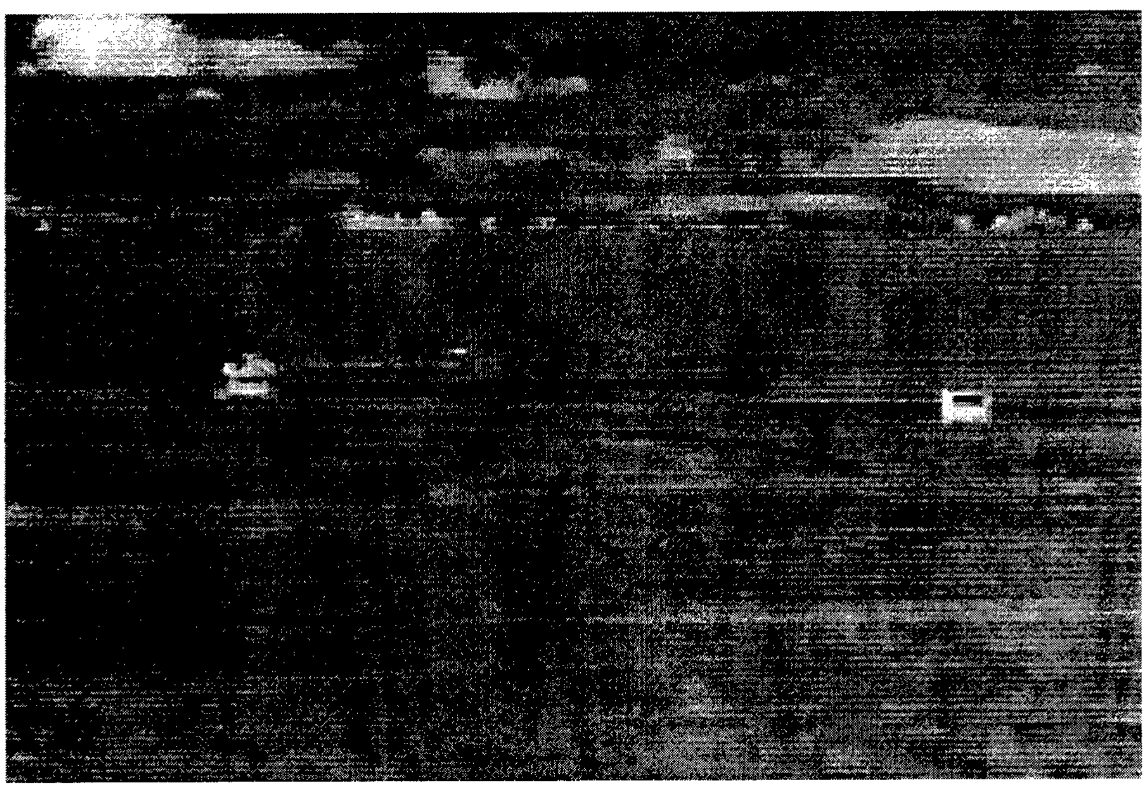

Figure 11. CITV Screen

3.3 Description of DIS Setup

The DIS test setup, shown in Figure 12, consisted of an M1A2 tank simulator, a remote commander's station, and a test director's area. The M1A2 tank simulator was operated by a gunner and a driver. The driver's station, which was from an M1A1 simulator, did not have a compass or bearing indicator. The M1A2 simulator was brought up as a single tank node on a local DIS network.

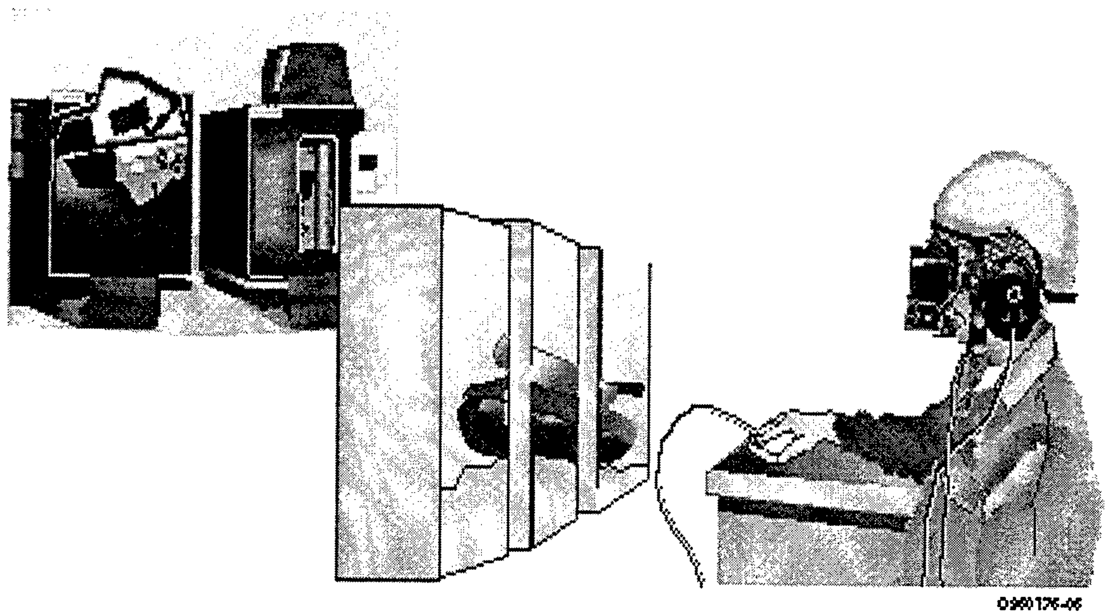

Figure 12. HMD DIS Testing Configuration

Testing in the DIS environment was attractive because it provided a semirealistic combat context in which to evaluate the tactical operational utility of the HMD and the enhanced user system. A major challenge for testing this system in the DIS environment, however, was that DIS is designed to simulate only in-hatch operations. Testing the enhanced user system required a way to maintain the combat realism while evaluating out-of-hatch operations. The problem was solved by seating the tank commander, not in the M1A2 simulator, but at a remote "stealth" station generally used by DIS operators or evaluators to oversee all DIS operations. The stealth station's viewpoint was slaved to the hull of the tank being simulated by the commander and crew in the simulator. Thus, the commander was seated in front of three 36-in. video monitors that simulated the external world view the commander would see when out of hatch.

The monitors had a field of view of about 120 deg directly in front of the tank. The view from the monitors was fixed to the hull direction and did not move with the turret. The setup did not allow the commander to view the areas to the side of the tank, only straight ahead. A control handle and CITV control panel were available at the remote station to give the commander control over panning of the CITV.

During all of the testing, the tank commander wore the CVCHMD. All of the soldiers were easily able to see the stealth monitors through the HMD, whether or not information was displayed on the HMD. The tank commanders wore the goggles over any corrective eyewear they normally used. The commanders also wore a standard CVC helmet with a radio headset.

The radio provided voice communications with the gunner and driver in the simulator. The radio was also used for communications with friendly forces simulated by the test director.

A software version of the CID called the InterVehicular Information System Emulator (IVIS-E) was modified with the enhanced user screens and functionality. The IVIS-E software was run on a SUN SPARCBOOK and displayed on the HMD. The SUN-based IVIS-E software ran on the same local DIS network and was assigned the same vehicle ID as the M1A2 simulator. This caused the IVIS-E software displayed on the HMD to behave as if it were the CID inside the M1A2 simulator's turret. The actual CID inside the simulator turret was disabled for all of the testing.

The commander interacted with the IVIS-E software running on the SUN using a mouse for cursor control. One of the early findings of this program showed that selection of a good cursor control device for an out-of-hatch system was a critical issue. Some of the ideas being considered include a remote handle with a four-direction thumb switch or a multibutton keypad on the commander's arm or mounted on the turret. Since it was beyond the scope of the program to design the cursor control device, a mouse was used for all of the tests. The commander had much finer control over cursor position with the mouse than would be available with a fielded cursor control device. The enhanced user screens, however, were designed to work with a much coarser level of cursor control. None of the enhanced user screens have more than nine areas that are cursor-selectable, and all of the selectable areas are kept large so they can be selected easily. The enhanced user screens also incorporate many shortcut buttons that allow common functions to be performed with little or no cursor movement.

The test equipment also included a video scan converter and line switcher. These were located near the commander's station and used to switch the HMD display between the enhanced user screens from the SUN and a simulated CITV image produced by the M1A2 tank simulator. The actual switching between enhanced user screens and CITV screens was controlled by the user selecting the CITV button on the enhanced user screens.

The test director's area included an SGI workstation that simulated semiautomated forces (SAFOR), both friendly and opposing. The test director's area included a SUN workstation running IVIS-E to simulate reports originating from other friendly tanks and a second SUN workstation running IVIS-E to simulate a unit further up the command chain that would receive reports generated by the tank commander. The test director's area had a radio headset for simulation of radio traffic from friendly forces as well as a SUN SPARCBOOK that collected screen use data during the testing.

3.4 System Changes for DIS Testing

Implementation of the enhanced user screens into the SUN-based CID software emulation and integration into the DIS facility required a few deviations from the way the system would work when fielded. The most significant change was in cursor control. An important finding of the earlier user jury review was that cursor control is a major issue for current and future tank-fielded systems. The development of a suitable cursor control device was beyond the scope of the DIS testing project, so the testing was done using a simple mouse for cursor control.

Limitations on time and funding also dictated that only a portion of the full CID functions were implemented and tested in the DIS facility. Only the functions available on the CID in combat

mode were implemented, and the types of reports that could be generated were limited to spot, contact, and call for fire reports.

The different video formats of the HMD, SUN, and CITV simulator made it difficult to overlay SUN-produced symbology on the CITV image in real time. Due to this difficulty, the enhanced CITV screens were not developed. The resulting DIS setup allowed either CID or CITV images to be displayed on the HMD but did not have CITV-specific enhanced screens overlaid on the CITV imagery.

3.5 Scenarios for DIS Testing

The baseline test scenario placed the test subject as the commander of a platoon of four simulated tanks. The location for the scenario was the Fort Knox area, which included quite steep terrain and was heavily wooded. The time of day was midday, and the weather was clear with good visibility. Enemy forces consisted of platoons of BMP-2 infantry fighting vehicles, T72 tanks, and two Hind helicopters. Friendly forces consisted of a single platoon of M1A2 tanks.

In the DIS testing, the tank commander under test acted as commander of the platoon in three separate scenarios. At the beginning of each scenario, the commander received a map overlay on the HMD showing the locations of six checkpoints. The commander's orders were to proceed to the checkpoints in a specified order and report any enemy contacts. They were told to engage the enemy when necessary and that they could call for fire support when they felt it was needed.

The three scenarios were long enough in duration that each of the enhanced user screens, as well as the CITV, were used many times. The only differences among the three scenarios were the locations of the checkpoints and the locations and composition of the enemy forces. The behavior of the enemy forces was controlled in real time by the SAFOR operator. Message traffic from other friendly units was also simulated in real time for each scenario.

3.6 DIS Testing Limitations

For several reasons, the DIS test setup was less than an ideal simulation for demonstrating how the system would be used in the field. Situation awareness limitations, implementation tradeoffs, and database limitations all contributed to reducing the realism of the tests.

One of the main reasons tank commanders would use an HMD is that it would allow them to spend more time out of hatch, increasing their situational awareness of what is going on in the battlefield. The limited field of view of the stealth monitors and the tank commanders' inability to turn their head and see other directions meant that they received much less visual information than would be present in the real world. Other information such as sounds, smells, and even the feel of the sun and wind add to increased situational awareness in the real world but were not present in the DIS facility. In addition, other activities ongoing in the facility caused distractions that would not be present in the field.

A few areas where the tank commanders' reduced situational awareness became apparent involved knowing the turret orientation and locations of the other tanks in their platoon. In the field, the orientation between the hull, turret, and tank commanders' gaze would be obvious, since they can see both the hull and turret with their peripheral vision. In the simulation, it was

possible for the commanders to become disoriented about where the gun tube was pointed. In the field, commanders would be able to keep track of other tanks in their peripheral vision or by using sound cues. In the simulation, peripheral vision was limited and there was no sound, so it was easy to lose track of other tanks.

Another limitation in the DIS setup was related to the terrain database used for the simulation. The database, depicting the Fort Knox area, was quite hilly and covered a limited area. At times it was difficult to place targets in the database that could be seen from a long distance. An artifact of this difficulty, combined with the limited resolution of the stealth monitors, resulted in the tank commanders getting quite close to targets before detecting them. The tank was often in the middle of a battle before a report could be sent out.

The limited map area also restricted the distances between checkpoints. With checkpoints close together, travel time between them was quite short, on the order of a few minutes. This affected the commander's use of the base screen and tactical map. The short distances between checkpoints, coupled with the lack of a compass for the driver, meant the commander had to continually monitor the tank's location relative to the next checkpoint. This monitoring was done with the tactical screen. While moving between checkpoints, the commander rarely used screens other than the tactical screen. In the real world, with greater distance between checkpoints, the commander would not have to monitor the tactical map continuously and could thus make more use of the other screens.

3.7 Test Subject Training and Familiarization

The subjects for the DIS testing were six soldiers from Fort Knox who were familiar with the M1A1 tank. The soldiers had a minimum of 10 years in the service with CID and M1A2 experience ranging from a few months of extensive use to only a few hours of familiarization training. Four other soldiers assisted the testing, acting as driver and gunner in the simulator and assisting the test director in simulating radio traffic.

The soldiers were trained in use of the enhanced screens and the HMD in two steps: first, using the screens on a workstation, and second, using the screens on the HMD. The purpose of the first training step was to familiarize the soldiers with the enhanced user screens and the general objectives and constraints of the DIS testing. During this step, each soldier was shown each of the enhanced screens and functions on a workstation. At the conclusion of the first training step, each soldier used the workstation-based enhanced user system until they felt comfortable with all of the functions. The functions they were asked to perform were: reading information from the base screen, bringing up the base screen at any time, bringing up the tactical grid screen, reading incoming messages, and sending out contact, spot, and call for fire reports. This first training step lasted about two hours for each soldier.

The second training step was to give the soldiers hands-on experience with the enhanced screens on the HMD. The soldiers started this step using the HMD in a static environment and progressed to using the HMD with the full simulation. During the second training step, each soldier made use of each of the enhanced screens as well as the CITV imagery.

By the end of the training, each soldier had a minimum of four hours' experience using the enhanced screens on the HMD in a full simulation environment. At the conclusion of the training, each soldier was tested to ensure that they could fully utilize the system. Based on the

qualification testing, all six soldiers were judged to be qualified to participate in the actual testing.

Section 4
Results and Discussion

4.1 First Impressions and Feedback During Training

During training and familiarization, the soldiers provided informal feedback on the enhanced user system and its design. This feedback fell into three main categories: screen layout, system function, and HMD physical build.

The comments about the screen layouts were generally favorable. Most soldiers thought that the base screen contained the right information and that the information was displayed appropriately. The soldiers thought that the compass rose at the top of the base screen was useful in the simulator because the hull and turret orientations were harder to see in the simulator. They felt that the compass would be less useful in a real-world situation where the hull and turret orientations would be obvious.

One feature the soldiers expressed interest in having added was a better way of alerting the user to new incoming messages. The default method was to put the new message title in the upper right corner of the screen. Most of the soldiers did not notice incoming messages until quite some time had passed. Some soldiers expressed interest in an audio tone alerting them to new messages, but others said there were already too many audio alerts in the tank.

Before actual testing began, a feature was added to the system that flashed the screen when a new message arrived. This helped alleviate the problem of missed messages but did not solve it. The soldiers still missed incoming messages, especially in times of high workload. One soldier wanted incoming messages to be displayed in the center of the screen immediately on arrival, but this approach was not favored by other soldiers.

The soldiers liked the translucent nature of the screens. They could easily watch the outside world displayed on the simulator monitors through even the most complex HMD screens. A downside of the translucent screens was the low contrast of the CITV imagery, especially when facing a bright or visually complex background. All of the soldiers had to look toward a smooth, dark surface when viewing CITV imagery on the HMD. This problem can be partially solved by increasing the contrast of the CITV imagery, but the issue of bright and busy backgrounds must be addressed before the system is tested outdoors.

In general, the soldiers' comments on the system's functionality were also favorable. Even soldiers with little CID experience were able to navigate between screens and functions effectively. The soldiers liked and made use of the shortcut keys to jump to often used functions.

Many of the soldiers' initial negative comments on the system functions related to bugs in the implementation that we were able to fix before the testing began. Other comments pointed toward desired changes in the underlying CID system design, regardless of whether it was used in or out of hatch. Most of the soldiers did not like the way reports were generated. In the current design, it is easy for commanders to lose track of where they are in the report-generation process. The soldiers wanted to be able to see a partial report as it was being created. This would give them feedback throughout the report-generation process. They also wanted a partially completed

report to be retained if they had to leave the report-generation function and come back at a later time.

The soldiers also wanted a quicker way to add a call for fire report. Currently, the system requires the soldier to re-enter target type and number information for a call for fire report. The soldiers would like information from the last report generated to be used as a starting point for generating a call for fire report.

The soldiers also wanted better feedback when they sent out a report. Often a soldier would generate a report and then forget to send it. Just as often the same report was sent multiple times because the commander did not remember if it had been sent.

The soldiers also had recommendations for new reports that should be added. They all expressed a need for an adjust fire report and a situation report. The adjust fire report would be a version of the call for fire report that retained target information but would allow for an update of location. The situation report had been left out of the system as a design decision, but the soldiers expressed a desire to have it put back into the system.

The final area of comments from the soldiers dealt with the physical build of the HMD. All of the soldiers expressed concern over the ruggedness of the HMD in the tough tank environment. It was reiterated to the soldiers that the particular HMD used in the testing was a laboratory prototype and that it would be reengineered for field use. In the design of a fielded system, careful consideration will have to be given to the harsh tank environment, including dust, weather, and the abuse that all tank-fielded systems must be able to withstand.

There were also some concerns over the fit of the HMD. A few soldiers had trouble getting the HMD to stay in place on their heads. The rigidity of the HMD housing and the weakness of the straps made it difficult to get a good fit, especially for soldiers with a narrower head size. At times, the HMD would slip down on the subjects' nose slightly, making it difficult for them to see the top of the display. During some of the tests, a few of the soldiers had to hold the HMD in place with one hand.

The issues discussed in this section of the report will have to be addressed before the system is tested on a tank. A redesign of the report-generation screens and a redesign of the HMD housing will have to be done before any system would be ready for field testing.

4.2 DIS Testing

The actual testing of the HMD enhanced user system was conducted by the Test and Evaluation Coordination Office of Fort Knox. TECO will publish a separate report of their test results. Highlights of their test results were pulled from a draft of their report and are summarized below.

The DIS tests were conducted over a one-week period at the Fort Knox Mounted Warfare Battle Lab. During the week of testing, each of the six soldiers went through the three scenarios at least once. After completing each scenario, the soldiers completed a survey of questions covering all aspects of the system, from individual screen layout and function to the general usability of the system.

The purpose of the DIS testing was to evaluate subjectively the utility, fightability, and survivability of using the HMD enhanced user system for out-of-hatch operations. The results of

the testing were gathered from the survey responses as well as debrief discussions with the soldiers after each test.

In response to the questions, the users reported that, in general, the screen layout and functions were good. They stated that the correct information was displayed on the screens and that the screens still allowed for adequate external visibility. The soldiers also reported that most of the system's functions were good, but that some improvements could be made, especially to the report-generation process. The general conclusions of the TECO testing were that the users agreed that the HMD-based enhanced user system would improve the fightability and survivability of the M1A2 tank, but that some changes were required to optimize the system. TECO also found that the CVCHMD system did not appear to create a task or information overload for the tank commander.

4.3 Advanced Screen/Enhancement Interviews

At the end of the DIS testing, interviews were conducted with some of the soldiers to get their comments on possible enhancements and changes to the enhanced user system. Five soldiers were interviewed after they had completed all of the DIS testing and questionnaires.

The first comments solicited from the soldiers during the interview were about the accuracy of the DIS simulated environment. They said that the simulation gave them a feel for how the enhanced user system would be used in the field, but that it lacked some important characteristics. The biggest concern was that in the simulation, the commander was not moving and subject to all of the vibration and bouncing experienced in the field. They felt the motion could have an impact on the usability of the system. Other comments about the simulation pointed out that the driver was not in an actual M1A2 driving station. This issue was addressed earlier in this report.

Other comments addressed the unrealistic nature of the simulated battles. In the DIS simulation, many battles took place with the commander out of hatch, whereas in the field, the commander would be buttoned up for the battles. A soldier brought up a concern pertaining to the reality of the simulated battles, pointing out that they had unlimited ammunition during the battles. Both of these issues were discussed during the design of the DIS test scenarios and considered of low significance because a large percentage of the enhanced user system's use takes place before a battle begins.

The next set of interview questions was designed to get the soldier's general impressions of the system and to gauge whether they liked it and would use it in the field. The comments were favorable. The soldiers liked the system and would use it 60% to 90% of the time they were out of hatch. They felt the system would give them more out-of-hatch time, reducing the need to jump down into the turret and thus minimizing wear and tear on their knees.

Many soldiers expressed disappointment over the quality of the CITV image. The low contrast of the signal made the CITV difficult to use. Some of the soldiers also had disorientation problems, not knowing where the CITV was pointed.

The interviews then moved to questions about more specific features of the enhanced user system. The first feature was the HMD hardware. The soldiers had some concerns over the fit and weight of the HMD hardware. Many of these concerns echoed those discussed earlier in this report.

The soldiers were also concerned with the durability of the HMD hardware, pointing out it would have to hold up to sand, rain, and soldier abuse. Many noted that the goggles they currently use are often removed quickly and thrown on the ground or the floor of the tank. They wanted to be able to remove the HMD quickly and also stressed that stowage of the HMD in the already cramped turret would be an issue. The cabling of the HMD to the turret was also raised as an issue. Soldiers stated that the cabling must not get in the way of other systems such as the machine gun. The weight of the cables and its impact on the overall weight and weight distribution of the HMD were also of concern.

The soldiers were very pleased with the transparent nature of the HMD screens. They felt it allowed them to monitor the outside world much better than an opaque screen. They also liked the biocular display arrangement rather than a monocular display.

Most of the soldiers would prefer an HMD where the image is presented on some type of full face shield. The shield could then be flipped out of the way when not needed.

The soldiers also expressed interest in a display that would mount somewhere on the outside of the turret, especially if the issues of display placement, cabling, and ruggedization could be overcome.

Another big topic of discussion during the interviews was the type of hand controller that should be used with an out-of-hatch CID system. Most soldiers agreed that the current commanders' handle, which uses a thumb switch for cursor control, will not work for cursor control out of hatch. It is too difficult to select menu items and buttons with the cursor using the switch on the commander's handle, even in an immobile tank. The soldiers felt that a simple tethered handgrip with switches for selecting menu items, or for moving the cursor up, down, left, and right, would work.

A few soldiers pointed out that fine cursor control is really only necessary for map overlay drawing tasks, which could be done in hatch. All out-of-hatch tasks could be done with a much coarser cursor control that would permit selection of items from a menu. Soldiers did not feel they needed access to any fire control functions with the HMD.

Soldiers were intrigued by the concept of a small keypad mounted somewhere on the outside of the turret. They did point out that installation of any controller would have to contend with issues of mounting and durability and could not interfere with the operation of other systems. They said that it is important to keep the commander's hands free or allow them to get free quickly to operate the machine gun. Any handheld device would also have to contend with issues of cabling and stowage.

The next section of interview questions asked about possible improvements and enhancements to the screen layouts and system functionality. A few of the soldiers wanted more shortcut options to get to higher use features and to jump through other features. Most of the soldiers thought that it would be nice to have some of the other CID features, such as diagnostics and overlay drawing, but none thought it was a high-priority addition.

The concept of a danger indicator received mixed reviews from the soldiers. Some thought it would be useful, but others were concerned about more text cluttering up the screens. There was a wide range of ideas for the kinds of data that should be considered in computing the danger indicator value. Some of the soldiers wanted minefield locations considered, and others did not.

It was clear that it will be difficult to design an algorithm to compute a danger indicator value that will please everyone.

All of the soldiers agreed that restricting the use of the HMD to outside the turret was a good idea. They thought that in the future, an HMD display could be useful for the loader and even the driver. The soldiers were unanimous in feeling that fire control and gunner's sight information should be left to the gunner and not provided on an HMD.

Looking further into the future, the possible benefits of a head tracker drew mixed reviews from the soldiers. Some thought it might be useful for slewing the CITV sensor, but none liked the idea of slewing the turret with a head tracker. Conformal map displays that would orient with the direction the commander turned his head were rejected as too confusing to decipher. The soldiers always want their maps oriented with north at the top. The idea of a three-dimensional perspective display received very mixed reviews. Some thought it would be great, but others thought it would be too confusing.

Section 5
Conclusions

Testing of the enhanced user system in the DIS facility showed that it would be a valuable enhancement to the M1A2 tank. The soldiers reported that they would use it and it would increase the time they would spend out of hatch. The general consensus was that the screen layouts and system functionality were good, needing only small changes.

Testing in the DIS facility gave soldiers a feel for how the system could help them in the field, but it did have some limitations. The next step is to put the enhanced user system into a tank to test the system in the field. Before a field-test can be conducted, a few issues need to be addressed, including ruggedization of the hardware, fit of the HMD, and improvements to the contrast of the display. Integration into a tank would also force the issue of hand controller design. It was clear from the testing that a new control device must be developed for this system to be effective.

The main conclusion of this project was that use of an HMD-based enhanced user system can improve the fightability and survivability of the M1A2 tank. This is done by allowing the tank commander to access vital information and communication functions while retaining external situational awareness by remaining out of hatch a greater percentage of the time. The HMD-based enhanced user system gives the tank commander the benefits of both long-range digital battlefield information as well as retaining short-range battlefield situational awareness by being out of hatch.

This document reports research undertaken at the U.S. Army Soldier and Biological Chemical Command, Soldier Systems Center, and has been assigned No. NATICK/TR-99/025 in a series of reports approved for publication.

Appendix Raw Post-Survey Answers

The following is the raw data from verbal post-test interviews with a few of the soldiers.

1.a What is your rank?

Sgt.

1. b. Years in service?

11-17

2. Tank experience?

M1A1, M1A2

4. CID and IVIS experience?

Some training, Has used, Since Oct., None

6. What features would you like to see added to the system:

Add SIT report, Flash for messages

flip out of the way, sit report, danger indicator

7. What did you like about HMD?

Quick, Good for initial contact

Quickness and ease of use, CITV, incoming message access

Good for localizing, can see where gunner lased

easy operation, base screen

8. What did you not like about the HMD?

Limited utility, only for offense, reenter cff data, keep overlay when reading messages

CITV Screen, differences from IVIS, top of display hard to see, no use inside tank

don't need CITV even if head tracker, weight and removability difficult

CITV orientation confusing

too heavy, nose heavy, restrictive to head, don't want handle

9. What changes should be made to the HMD?

Full shield, not goggles

put on tank - cable issues

weight, attach to CVC, anything hanging will get in way

durability

lighter, controller, face guard, protective chem gear

10. How would HMD change existing procedures?

less jumping up and down

quick tracking, wear and tear on knees

easier localizing, orientation, see threats ahead of time

more out-of-hatch time

11. What was unrealistic about the DIS tests?

tank sim not A2

shootouts and helicopter

missing small movements

unlimited ammo, shakiness

12. How much would you use HMD in the field?

goggles 10% - full shield 80%

70-90%

depends on situation, weather, desert where goggles all of the time

13. Is using an HMD out of hatch a good idea?

yes

14. How about inside the tank?

no

15. Would you recommend an HMD for other crew members?

Loader & driver, monitor IVIS, driver waypoints, loader info management offload

16. Do you fire the gun while out of hatch?

no

17. What fire control functions do you want on the HMD?

Gunner's problem

CITV range indicator larger

no

add gun position and last lase

18. Would you like gunner's sight images displayed on the HMD?

No

would like to have, would like to shoot

no

good in defense-traverse, CITV would be a blur, magnification help, nice to have

23. Are there any changes you would like to see in the IVIS system?

shortcut to avoid confirm step

25. Do you agree with our decision to not implement PRE and POST system modes?

yes

26. Are there some pre and post functions to include for out of hatch?

nice to have

27. Is a danger indicator a good idea?

no, more to get in the way

OK

yes, but add to IVIS also

maybe if in conjunction with messages

28. How do you like the five-scale danger indicator?

priority on message flash

don't take our gun binary buttons

numbers good & sufficient, could tie to SOP

tone might be needed

29. What other information could be included in the danger indicator?

getting into killing range of unread report

not minefield data if on overlay

mine indicator, message priority

33. How would you attach a CID on the outside of the tank?

stick it on

needs to be very durable

could get in the way of gun

get in the way, hard to protect

danger prone, won't survive

34. Would such an approach be preferable over an HMD?

if cordless

yes

would rather have than goggles

35. Would you like a handheld pen-based portable CID?

stickable to ring - no pen

cableless would be great

where to stow, cable tangle in gun system

where to plug it in, problems remembering to bring in turret, leave outside

pro: working with graphics; con: having to hold still, shifting gaze during movement

36. Would you prefer handheld over HMD-based?

faceplate, mounted, clipboard, HMD

anything on HMD must be easy to get out of the way

37. How do you feel about a monocular HMD rather than a biocular one?

face shield probably best, glasses a problem with goggles, but most soldiers don't wear them

38. How would you like an opaque rather than a see-through HMD?

against monocular

ditto - like the night vision goggles, will get broken if it sticks out

one screen problem, annoying to divert focus

nothing hanging off side of HMD

see-through the best

42. How durable must the HMD be?

very hardened - they throw them on the ground

44. Do you have any preferences for input devices for this system?

hand carried is a problem, M1A1 clip-on idea works well, fine resolution needed for map only

liked keypad

no Morse code

45. Should the input device be handheld or mounted in turret?

sholder mounted

handheld must permit gun use, keyboard appropriate, small with stylus, don't like coolie hats

46. Other types of hands-off devices?

voice, voice IVIS (ECOM) under way, not thrilled with error rates, hand control for now

50. What do you think of using a system with a head tracker and conformal displays?

no use

don't like map moving, want north up

possible confusion with hull, gun, gaze direction and IVIS map

52. How important is conformal displays capability?

important later but not so much for displays

53. How would you like a head tracker that moves the CITV sensor with your gaze?

nice to have

no

good idea

55. How would you like a head tracker that moves the gun turret?

no way

taking duties from gunner

50 cal might be useful

nice to have, possible problems with gun directing

57. Would you like the tactical map displayed in a perspective view?

not much use

would like color topo maps

very good and useful